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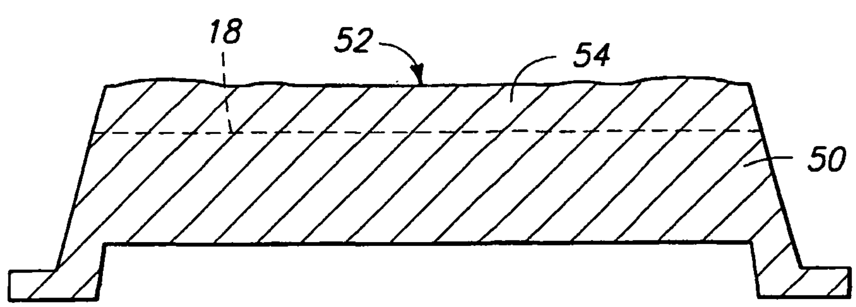
(54) **Title:** METHODS OF FORMING SPUTTERING TARGETS, AND SPUTTERING TARGETS FORMED THEREBY



(57) **Abstract:** The invention encompasses a method of forming a sputtering target. A wear profile for a sputtering target surface is determined. The wear profile is utilized to generate a desired profile for a sputtering target sputtering surface. A sputtering target is formed having a sputtering surface with the desired profile. The invention also encompasses a sputtering target having several sputtering domains which reflect the magneti type. The invention also encompasses a sputtering target having a sputtering domain which includes an edge region and a central region. The edge region of the sputtering domain is thicker than the central region.

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Methods Of Forming Sputtering Targets, And Sputtering Targets Formed Thereby

TECHNICAL FIELD

The invention pertains to methods of forming sputtering targets, and further encompasses the targets formed by the methods.

BACKGROUND OF THE INVENTION

A sputtering method is described with reference to Fig. 1, which illustrates a sputtering target 10 spaced from a substrate 12 by a distance T/S. Distance T/S is referred to as the target to substrate distance. Substrate 12 can comprise, for example, a semiconductive material wafer. Target 10 can comprise numerous materials known to persons of ordinary skill in the art, such as, for example, metallic materials (e.g. one or more of aluminum, copper, titanium, tantalum, tungsten, cobalt, nickel, etc.), or ceramic materials (e.g., $BaTiO_3$, $Pb(Zr, Ti)O_3$, $BiSrTaO_3$, etc.). Also, target 10 can comprise numerous shapes. For instance, Fig. 2 illustrates that target 10 can comprise a circular shape. The target of Figs. 1 and 2 has a approximately the shape of an ENDURA™ target, available from Honeywell International, Inc.

Referring again to Fig. 1, a shield 14 is provided over a peripheral region of target 10. Shield 14 can comprise, for example, stainless steel or aluminum.

In operation, material from target 10 is sputter-deposited onto substrate 12. More specifically, target 10 has a face surface 16 which is exposed to high energy ions and/or atoms. The high energy ions and/or atoms eject atoms from surface 16, and the ejected atoms are subsequently deposited onto substrate 12. Shield 14 protects peripheral edges of target 16 from being exposed to the high energy ions and/or atoms. One of the goals in target fabrication is to deposit a uniform film of material over substrate 12 during an extended target life. One aspect of achieving a uniform film is to have an appropriate T/S distance between target surface 16 and substrate 12, as well as to maintain a substantially common T/S distance from the entirety of the sputtered target face 16 and substrate 12. Shield 14 is provided to alleviate problems which could

occur if the sloped regions of target 10 were exposed to high energy ions and/or atoms during a sputtering process.

Fig. 3 illustrates target 10 after the target has been subjected to the wear of having material sputtered therefrom. Specifically, Fig. 3 illustrates a wear profile formed across sputtered face surface 16. The illustrated wear profile is for exemplary purpose only. The shape of an actual wear profile can depend on, for example, the magnet type and target life of materials used in a sputtering process. A dashed line 18 is provided in Fig. 3 to illustrate the starting position of the face surface when target 10 was new (i.e., the face surface shown in Fig. 1). As shown in Fig. 3, a number of troughs (i.e., sputter tracks) are formed within face surface 16 during the sputtering operation. Accordingly, the target does not wear uniformly across the surface 16.

Attempts have been made to improve target lifetime by adding additional material to a target to compensate for the uneven wear pattern of Fig. 3. For instance, Fig. 4 illustrates a target 20 which attempts to compensate for the uneven wear of Fig. 3. Target 20 is shown with a dashed line 18 illustrating the position of original face 16 in the target 10 of Figs. 1-3. Fig. 4 also shows additional material 22 provided over original position 18, and in locations which compensate for the uneven wear profile of Fig. 3. Accordingly, target 20 has a face surface 24 which effectively comprises a mirror image of the wear profile of Fig. 3.

Fig. 4 is one embodiment of prior art processes for compensating for the uneven wear profile of Fig. 3. Another embodiment is to simply form additional material 22 over various regions of 18, without necessarily creating a mirror image of the wear of Fig. 3. Regardless of which of the prior art techniques is utilized, the result is a target having relatively large peaks at positions in which wear has been most significant in prior targets. A difficulty with the processing of Fig. 4 is that target 20 has large variations in thickness across its surface, and accordingly a T/S distance relative to face 24 of target 20 varies significantly across the face. Accordingly, the uniformity of film deposition from target 20 can be significantly worse than the uniformity of film deposition from a target having a planar face. Thus, even though lifetime can be improved utilizing the

target 20 of Fig. 4 instead of the target 10 of Figs. 1-3, the loss in uniformity can render target 20 less desirable than previous targets 10 of Figs. 1-3.

It would be desirable to develop techniques for forming targets having improved lifetimes, and which can be utilized to uniformly sputter-deposit materials on substrates.

SUMMARY OF THE INVENTION

In one aspect, the invention encompasses a method of forming a sputtering target. A wear profile for a sputtering target surface is determined. The wear profile corresponds to a shape of the target surface after the target is subjected to the wear of having material sputtered therefrom. The wear profile is divided amongst a plurality of datapoints across the target surface. A difference in height of the target surface after the wear relative to a height of the target surface prior to the wear is calculated. The difference in height calculations generate a plurality of wear definition datapoints. Target lifetime datapoints are calculated using the wear definition datapoints, and sputtering uniformity datapoints are also calculated using the wear definition datapoints. A difference between the target lifetime datapoints and sputtering uniformity datapoints is calculated. A constant corresponding to the difference between a target lifetime datapoint and a sputtering uniformity datapoint is added to the sputtering uniformity datapoints to generate a desired profile for a sputtering target sputtering surface. A sputtering target is formed having a sputtering surface with the desired profile.

The invention encompasses another method of forming a sputtering target. A wear profile for a sputtering target surface is determined. The wear profile is divided amongst a plurality of datapoints to generate datapoints$\{S_1 \ldots S_i\}$, where "i" is a positive integer. Also, datapoints are generated to define the target surface prior to the wear, with the datapoints being $\{R_1 \ldots Ri\}$. Difference datapoints $\{A_1 \ldots A_i\}$ are generated, with each datapoint A_n being defined as $R_n - S_n$. Target lifetime datapoints $\{B_1 \ldots B_i\}$ are calculated. Each datapoint B_n is defined as$((A_n * y) + Q)$; where y is a constant greater than 0, and Q is a constant which can be 0. Sputtering uniformity datapoints $\{C_1 \ldots C_i\}$ are calculated, with each datapoint C_n being defined as $((A_n * z) + P)$; where z is a

constant greater than 0 and less than y, and where P is a constant which can be 0. Difference datapoints $\{D_1 \ldots D_i\}$ are calculated, with each difference datapoint D_n being defined as $(B_n - C_n)$. The difference datapoint having the greatest magnitude is determined, and is defined as D_{max}. A desired profile dataset $\{E_1 \ldots E_i\}$ is generated, with each datapoint E_n being defined as $(C_n + D_{max})$. A sputtering target is formed to have a sputtering surface with a profile corresponding to the desired profile dataset.

In yet another aspect, the invention encompasses a sputtering target having a sputtering domain which includes an edge region and a central region at least partially surrounded by the edge region. The edge region of the sputtering domain is thicker than the central region.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are described below with reference to the following accompanying drawings.

Fig. 1 is a diagrammatic, cross-sectional view illustrating a prior art sputtering target and substrate. Fig. 2 is a view along the line 2-2 of Fig. 1.

Fig. 3 is a diagrammatic, cross-sectional view of a prior art sputtering target after the target has been subjected to the wear of a sputtering operation.

Fig. 4 is a diagrammatic, cross-sectional view of a prior art sputtering target illustrating prior art methodology for increasing the lifetime of a sputtering target.

Fig. 5 is a flow chart diagram describing a method encompassed by the present invention.

Fig. 6 is a diagrammatic, cross-sectional view of a target which has been subjected to the wear of a sputtering operation, and specifically illustrates the target of Fig. 3. Fig. 6 also illustrates datapoints defined across the target surface for utilization in embodiments of the present invention.

Fig. 7 illustrates a curve generated in accordance with the present invention from the datapoints of Fig. 6, and specifically illustrates a curve comprising target lifetime datapoints.

Fig. 8 illustrates a second curve generated in accordance with the present invention from the datapoints of Fig. 6, and specifically illustrates a curve comprising sputtering uniformity datapoints.

Fig. 9 illustrates a difference curve generated by subtracting the Fig. 8 curve from the Fig. 7 curve.

Fig. 10 illustrates a desired target surface profile determined by adding a parameter determined from the Fig. 9 curve to the datapoints of the Fig. 8 curve.

Fig. 11 illustrates a cross-sectional view of sputtering target having a surface with the desired profile of Fig. 10.

Fig. 12 is a diagrammatic, top view of a sputtering target encompassed by the present invention.

Fig. 13 is a diagrammatic, fragmentary, cross-sectional view of the portion of Fig. 12 indicated by line 13-13.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention encompasses methodology for target design which can be utilized for designing desired profiles for sputtering target design so that the sputtering targets will have improved lifetime, and so that the sputtering targets will also sputter material to a desired uniformity. Methodology of the present invention can be utilized for improving sputtering targets of any shape, and comprising any material. One aspect of the invention is described with reference to a flow chart of Fig. 5, and illustrations of Figs. 6-11.

Referring to Fig. 5, an initial step of the shown embodiment is to measure a wear profile from a used sputtering target. Such is illustrated in Fig. 6, wherein the used sputtering target described previously with respect to Fig. 3 is shown. A wear profile of the sputtering target can be measured with, for example, a coordinate measuring machine. Fig. 6 shows the target 10 of Fig. 3, and shows a distance "X" relative to an initial upper surface 18 of target 10. Distance "X" can comprise, for example, about 1 ½ inches. Fig. 6 also shows a plurality of datapoints $\{A_1 \ldots A_i\}$ (wherein i is an integer

greater than 0). Fig. 6 actually shows only the four datapoints $\{A_1 \ldots A_4\}$, but it is to be understood that numerous other datapoints could be acquired and processed in addition to the shown datapoints. The datapoints can be across an entirety of a sputtering target face. It is noted that although the invention is described with reference to a process wherein a target wear profile is measured, it is to be understood that a target wear profile can be determined in other ways, such as, for example, by a computer-generated model of the wear profile rather than an actual measurement of the wear profile.

The datapoints $\{A_1 \ldots A_4\}$ correspond to differences between the worn surface 16 and the initial surface 18. In practice, surface 18 is initially divided amongst a plurality of datapoints $\{R_1 \ldots R_i\}$, which, for the shown planar surface 18 will be the same as one another. Also, the worn surface 16 is divided into a plurality of datapoints $\{S_1 \ldots S_i\}$, and the datapoints $\{A_1 \ldots A_i\}$ are determined as a difference between the datapoints R and the datapoints S. Specifically, a datapoint A_n is defined as $R_n - S_n$. The calculations of $\{A_1 \ldots A_i\}$ correspond to step 102 of Fig. 5, which indicates that an amount of wear is calculated at a plurality of regions of a target by determining the amount of target removed at the regions. Each of the datapoints $\{A_1 \ldots A_i\}$ corresponds to one of the regions referred to in step 102. In the shown embodiment, A_1, A_2, A_3 and A_4 have values of 4, 9, 4 and 6, respectively. The values are relative values of A_1, A_2, A_3 and A_4 to one another, and are provided for comparison of A_1, A_2, A_3 and A_4. The values have units of length, but no particular units are assigned to the values used herein as the values are for illustrative purposes only and do not correspond to actual measured values.

The number of datapoints $\{A_1 \ldots A_i\}$ that are calculated can vary depending on the processing equipment and time available. It can be desired to utilize a large number of datapoints $\{A_1 \ldots A_i\}$ in that such will generally better characterize target wear than will fewer datapoints. However, a large number of datapoints will take more processing time than will fewer datapoints. In an exemplary embodiment, the number of datapoints is chosen so that spacing between adjacent datapoints is from about 0.05 inch to about 0.5 inch.

Referring to step 104 of Fig. 5, a plurality of target lifetime datapoints are calculated for the regions corresponding to $\{A_1...A_i\}$. Such calculation generates the curve shown in Fig. 7. More specifically, Fig. 7 illustrates a curve comprised of a plurality of target lifetime datapoints $\{B_1...B_i\}$. Each of the datapoints B_n is defined as $((A_n * y) + Q)$, where y is a constant greater than 0, and Q is a constant which can be 0. The constant y is defined as a target lifetime parameter. The target lifetime parameter can be from greater than 0 to 1, and is typically from 0.2 to 0.9, commonly from 0.2 to 0.5, with 0.33 being an exemplary number. Ultimately, the target lifetime parameter can determine how much material is added to a target to increase the target lifetime. It can be preferred that a target lifetime be an integral of the lifetime of shields used around a periphery of the target (such as, for example, shields 14 of Fig. 1). For instance, if the shields have a lifetime of about 300 kilowatt hours it can be desirable that a target have a lifetime of either 600 kilowatt hours, 900 kilowatt hours, or 1200 kilowatt hours. Prior art targets have been produced having uncertain lifetimes. It would be desirable to develop targets having substantially exact lifetimes triple or quadruple the lifetime of shields. Methodology of the present invention can enable quality targets to be produced which have lifetimes of triple or more the lifetime of shields, or which match the life of extended life shields. The target lifetime parameter enables a lifetime of a target to be manipulated.

In the embodiment shown in Fig. 7, the target lifetime parameter is 0.5 and the constant Q is 0. Accordingly, in the shown embodiment in which A_1, A_2, A_3 and A_4 are 4, 9, 4 and 6, respectively; B_1, B_2, B_3 and B_4 are 2, 4.5, 2, and 3, respectively. The curve B is shown drawn relative to a dashed coordinate 30. Coordinate 30 is defined by the parameter "Q". The constant Q can correspond to, for example, the distance "X" of Fig. 6, or can be any other number.

Referring to step 106 of Fig. 5, sputtering uniformity datapoints are determined for the various regions defined by datapoints $\{A_1...A_i\}$. Such is illustrated in Fig. 8, wherein the sputtering uniformity datapoints are shown as $\{C_1...C_4\}$. In practice, a plurality of datapoints $\{C_1...C_i\}$ are defined from the plurality of datapoints $\{A_1...A_i\}$.

Each datapoint C_n is defined as $((A_n*z)+P)$, where z is a constant greater than 0 and less than y, and where P is a constant which can be 0. The constant z is defined as a sputtering uniformity parameter. In practice, z is usually from about 0.001 to 1, and can be from about 1/16 to about 1/6. The magnitude of z can depend on, for example, one or more of a magnet type utilized in a sputtering process, a target-to-substrate distance utilized in a sputtering process, a sputtering chamber configuration, and a target composition The datapoints $\{C_1...C_i\}$ define a curve which could be utilized to form a target surface that would lead to a high uniformity of deposited material on a substrate. However, such target surface would not have a lifetime significantly improved relative to the original target surface 18 (Fig. 6).

Fig. 8 shows a curve generated using z= 1/8, and specifically shows C_1, C_2, C_3 and C_4 equal to 0.5, 1.125, 0.5 and 0.75, respectively. The curve of Fig. 8 is shown relative to a coordinate 32. Coordinate 32 is defined by constant P and can, for example, correspond to the value "X" of Fig. 6. It can be preferred that coordinate 32 be identical in magnitude to coordinate 30 of Fig. 7, and accordingly it can be preferred that the constant P utilized to generate datapoints $\{C_1...C_i\}$ be identical to the constant Q utilized to generate datapoints $\{B_1...B_i\}$.

Referring to step 108 of Fig. 5, a maximum difference between the target lifetime datapoints and the sputtering uniformity datapoints is determined. Such is illustrated in Fig. 9, wherein a curve is generated by subtracting the curve of Fig. 8 from that of Fig. 7. Specifically, a plurality of values $\{D_1...D_i\}$ are generated with each value D_n corresponding to B_n-C_n. The shown curve comprises D_1, D_2, D_3 and D_4 corresponding to 1.5, 3.38, 1.5 and 2.25, respectively. The largest difference is referred to as D_{max}, and in the shown embodiment corresponds to the 3.38 of D_3. The curve of Fig. 9 is shown relative to a coordinate 34. Coordinate 34 is determined by the difference between Q and P. If parameter Q equals parameter P then coordinate 34 will be 0. If Q is different than P, coordinate 34 will have a value, and coordinate 34 can comprise either positive or negative value. It can be preferred for P to equal Q, and accordingly for coordinate 34 to equal 0.

Referring to step 110 of Fig. 5, the value D_{max} is added to the uniformity datapoints of Fig. 8 to generate a desired target surface profile. The desired target surface profile is shown in Fig. 10, and comprises a plurality of datapoints $\{E_1 \ldots E_i\}$. Each of the datapoints E_n is calculated as $C_n + D_{max}$, with the values C_n being those shown in Fig. 8. In the shown embodiment, E_1, E_2, E_3 and E_4 correspond to 3.88, 4.51, 3.88 and 4.13, respectively. It is noted that values other than D_{max} can be added to the uniformity parameters of Fig. 8 to generate a desired target profile. However, if values less than D_{max} are utilized, the target lifetime will be less than if D_{max} were used; and if values greater than D_{max} are utilized, the resulting target may be too thick to be used in desired applications. In the embodiment described herein, D_{max} is an additive value calculated from the target lifetime datapoints, and is added to the uniformity datapoints of Fig. 8 to generate a desired target surface profile. It is to be understood that the invention encompasses utilization of additive values other than values calculated from target lifetime datapoints in generating a desired target profile from sputtering uniformity datapoints, but such can be less preferred in that it can render it difficult to accurately control target lifetime.

Referring to step 112 of Fig. 5, the data from Fig. 10 is utilized to form a target having a surface with a desired target surface profile. Such is shown in Fig. 11, wherein a target 50 is shown having a surface 52 generated with the profile of Fig. 10. Target 50 has a shape corresponding to that of the target that generated the wear pattern of Fig. 3 with additional material defined by the data from Fig. 10 provided to form surface 52. More specifically, a dashed line 18 is shown to illustrate where the initial target of Fig. 3 would have had an upper surface. Additional material 54 is shown provided over dashed line 18, with additional material 54 corresponding to the profile of Fig. 10. Additional material 54 has the surface 52. Surface 52 defines a maximum target thickness determined by the target lifetime parameter y (assuming that D_{max} is used with the curve of Fig. 8 to generate the desired target surface profile), and accordingly will lead to a target having a desired lifetime. Further, profile 52 has a surface planarity defined by the target uniformity parameter z, and accordingly will sputter deposit-

material to a desired uniformity on a substrate. Accordingly, methodology of the present invention can provide a target having a desired lifetime, and also a desired sputtering uniformity. The parameters y and z can be determined to match desired specifications for particular target applications. The target of Fig 11 has a sputtering surface which includes peaks (or, in other words, outwardly extending portions) at high-erosion-rate regions and valleys (or, in other words, inwardly extending portions) at low-erosion-rate regions.

Figs. 12 and 13 illustrate a further aspect of the present invention. Referring initially to Fig. 12, a sputtering target 200 is illustrated in top view. Sputtering target 200 comprises a flange domain 202, an intermediate domain 204, and a sputtering domain 206. The sputtering domain 206 is defined as a region or thickness of target 200 from which material is sputtered during a sputtering operation. In contrast, flange domain 202 and intermediate domain 204 are regions from which material is generally not sputtered (note that the flange domain and intermediate domain would be protected by the shield 14 of Fig. 2), and therefore are distinct from sputtering domain 206 in a sputtering operation.

Fig. 13 illustrates a diagrammatic, cross-sectional view of a portion of target 200, and shows elevational relationships of flange domain 202, intermediate domain 204 and sputtering domain 206. Sputtering domain 206 comprises a first surface 208 and a second surface 210 in opposing relationship to first surface 208. First surface 208 can be referred to as a sputtering surface, and surface 210 can be referred to as a back surface. Material is generally not sputtered from the back surface 210 of the sputtering domain 206 during a sputtering operation because the operation is typically halted before a sputter track penetrates entirely through a thickness of sputtering domain 206. The back surface will typically ultimately be provided proximate a cooling device and/or a magnet during a sputtering operation. Sputtering domain 206 comprises an edge region 212 and a central region 214. Edge region 212 can be considered to be a high erosion region and central region 214 can be considered to be a low erosion region, in that edge region 212 typically erodes more rapidly during a sputtering process than

does central region 214. It is to be understood that although the invention is described relative to a target in which the edge region is a high erosion region and the central region is a low erosion region, the relative erosion rates of the central and edge regions can be reversed with various target designs and magnet types. The invention can be utilized with target designs in which the central region has a high erosion rate and the edge region has a low erosion rate by reversing a bottom surface profile described below.

One of the problems encountered in target utilization is that a low-erosion-rate region (the central region of the illustrated embodiment) will become thicker than a high-erosion-rate region (the edge region of the illustrated embodiment) during utilization of a target. The increased thickness of the low-erosion-rate region can reduce a current density throughout such region relative to the current density at high-erosion-rate regions of the sputtering domain. In the shown embodiment, such can cause reduced sputtering from the central region relative to that occurring at the edge regions; and accordingly can cause the central region to become increasingly thicker relative to the edge regions. Ultimately, the sputtering target performance is degraded to the point that the properties of thin films formed from the target (such as thin film uniformity across a wafer) are outside of desired tolerances, and the target is replaced. One aspect of the present invention is a recognition that the useful lifetime of a target can be increased if the target is constructed to delay the onset of problems associated with a thick low-erosion-rate region and a thin high-erosion-rate region (a thick central portion and a thin edge portion in the shown embodiment). Another aspect of the invention is a recognition that one of the expenses associated with targets is the cost of the raw materials. Accordingly there can be some savings in the cost of target production if less material is utilized in the central region of a target.

Fig. 13 illustrates a target constructed to delay problems associated with a thick low-erosion-rate portion and a thin high-erosion-rate portion. In the shown embodiment in which the central portion is the low-erosion-rate portion and the edge portion is the high-erosion-rate portion, the target is initially constructed with central portion 214 being

thinner than edge portion 212. Specifically, central portion 214 is preferably thinner than edge portion 212 by more than 0% for a planar target or an ENDURA™ target; preferably by more than 5% for either planar or ENDURA™ targets; more preferably by from about 11% to about 90% for either planar or ENDURA™ targets, and yet more preferably by from about 11% to about 70%. A typical difference in thickness of central portion 214 to edge portion 212 can be about 30%, which can, in particular embodiments, correspond to about 0.35 inches. There can be a particular advantage to having central portion 214 thinner than edge portion 212 by more than 11% for an ENDURA™ target, in that such can improve uniformity of magnetic flux density across a sputtering surface of the target during a sputtering operation relative to the uniformity of magnetic flux density that would otherwise exist.

In the shown construction, back surface 210 comprises a substantially planar portion 216 at edge region 212, and an angled region 218 between substantially planar portion 216 and central region 214. Angled region 218 is angled relative to substantially planar portion 216 by an angle "A" of greater than 1°, preferably of from greater than 1° to about 60°, and more preferably of from greater than 1° to about 45°. A typical angle is from about 2° to about 10°, and the shown angle is about 2.5°. The shown angle is measured from about a 4.4 inch radius of a target (relative to an outer side surface of the target), but it is to be understood that the angle can be measured from other locations, such as, for example, at any location from a 0" radius to a 6.3" radius; including a location at the outermost edge of the sputtering domain. Preferably the angle will start after a primary erosion area of a target (the deep erosion area, or trough, of FIG. 3), and it can also be preferable that the angle start after a secondary erosion area of a target (the less deep erosion area, or trough, of Fig. 3).

The incorporation of angle "A" into back surface 210 creates a target having a thinner central region of the sputtering domain than an edge region of the sputtering domain. The reduced thickness of the central region can cause increased current density through the central region, and an associated increased sputtering of the central region relative to the amount of sputtering which would occur if the central region were

thicker. Accordingly, the utilization of the thin central region can increase the useful target lifetime.

Alternatively, the incorporation of angle "A" into back surface 210 can be considered to form a concavity which extends into the back surface and toward the sputtering surface 208. In the shown embodiment, an entirety of the concavity is within the sputtering domain 206, and more specifically, an entirety of the concavity is within the low-erosion-rate region of the sputtering domain.

An additional advantage of methodology of the present invention is that such can enable magnetic flux density to be controlled to be uniform across a target surface. This can be of particular significance for magnetic materials such as Ni, Co and alloys of either Ni or Co.

The embodiment described with reference to Figs. 12-13 can be utilized in combination with the methodology of Figs. 5-11 to create sputtering targets having tailored sputtering surfaces and tailored back surfaces in opposing relation to the sputtering surfaces. Alternatively, the methodology of Figs. 12 and 13 can be utilized in combination with prior art sputtering targets to form sputtering targets having relatively flat sputtering surfaces and opposing back surfaces which are angled so that a central region of a sputtering domain is thinner than an edge region of the sputtering domain.

Although the methodology of Figs. 12-13 is described with reference to monolithic targets, it is to be understood that the invention can also be utilized with non-monolithic target designs. A non-monolithic target design would typically comprise a sputtering target bonded to a backing plate. In incorporating the methodology of Figs. 12 and 13 into fabrication of non-monolithic target designs, the sputtering target can be formed to have a concavity in its back surface so that a central region of a sputtered portion of the target is thinner than edge regions of the sputtered portion of the target.

CLAIMS

1. A sputtering target, comprising:

a sputtering domain, the sputtering domain comprising a thickness of sputtering material between a first surface and an opposing second surface, the first surface being a sputtering surface and the second surface being a back surface; the sputtering domain further comprising a high erosion region and a low erosion region; and

the back surface angling toward the sputtering surface to reduce the thickness of the sputtering domain in the low erosion region relative to the thickness of the sputtering domain in the high erosion region; the sputtering domain being more than about 5% thicker in the high erosion region than in the low erosion region.

2. The target of claim 1 being shaped as an ENDURA™ target.

3. The target of claim 1 wherein the difference in thickness of the high erosion region to the low erosion region is from about 11% to about 90%.

4. The target of claim 1 wherein the difference in thickness of the high erosion region to the low erosion region is from about 11% to about 70%.

5. The target of claim 1 wherein the sputtering surface has a desired profile having peaks at the high erosion regions and valleys at the low erosion regions.

6. The target of claim 1 wherein the sputtering surface has a desired profile generated by a method comprising:

determining a wear profile for the sputtering target surface, the wear profile corresponding to a shape of the target surface after the target is subjected to the wear of having material sputtered therefrom;

calculating an amount of wear at a plurality of positions of the target surface;

multiplying the amount of wear at the positions by a sputtering uniformity parameter to obtain sputtering uniformity values for the positions, the sputtering uniformity parameter being from 1/16 to 1/6;

adding an additive value to the sputtering uniformity values to generate the desired profile for a sputtering target sputtering surface; and

forming the sputtering target with the sputtering surface having the desired profile.

7. A sputtering target which comprises, during a sputtering operation:

a sputtering domain comprising a sputtering surface and a backside surface in opposing relation to the sputtering surface;

a uniform magnetic flux density across the sputtering surface; and

a concavity extending into the backside surface and toward the sputtering surface; the concavity being entirely within the sputtering domain of the target.

8. The target of claim 7 comprising one or both of nickel and cobalt.

9. The target of claim 7 comprising one or more alloys comprising one or both of nickel and cobalt.

10. The target of claim 7 wherein the sputtering domain comprises a high-erosion-rate region and a low-erosion-rate region, and wherein an entirety of the concavity is contained within the low-erosion-rate region of the sputtering domain.

11. A sputtering target, comprising:

a sputtering domain, the sputtering domain comprising a thickness of sputtering material, said thickness having a first surface and an opposing second surface, the first surface being a sputtering surface and the second surface being a back surface; the sputtering domain further comprising an edge region and a central region surrounded by the edge region;

a substantially planar portion of the back surface within the edge region; and

wherein the back surface includes an angled region between the central region and the substantially planar portion, the angled region having an angle of from greater than 1° to about 60° relative to the substantially planar portion.

12. A sputtering target, comprising:

a sputtering domain, the sputtering domain comprising a thickness of sputtering material, said thickness having a first surface and an opposing second surface, the first surface being a sputtering surface and the second surface being a back surface; the sputtering domain comprising an edge region surrounding a central region; and

the thickness of the sputtering domain varying from the edge region to the central region, and being at least 5% thicker at the edge region than at the central region.

13. The target of claim 12 being shaped as an ENDURA™ target.

14. The target of claim 12 wherein the difference in thickness of the edge region to the central region is from 11% to 90%.

15. The target of claim 12 wherein the difference in thickness of the edge region to the central region is from 11% to 70%.

16. The target of claim 12 wherein the difference in thickness of the edge region to the central region is at least about 30%.

17. The target of claim 12 wherein the difference in thickness of the edge region to the central region is at least about 0.35 inches.

18. The target of claim 12 further comprising a substantially planar portion of the back surface at the edge region, and wherein the back surface includes an angled region between the substantially planar portion and the central region, the angle of the angled region being from greater than 1° to about 60° relative to the substantially planar portion.

19. The target of claim 12 comprising metallic materials.

20. The target of claim 12 comprising one or more of nickel, aluminum, copper, titanium, tantalum, tungsten and cobalt.

21. The target of claim 12 comprising one or more alloys having one or more of nickel, aluminum, copper, titanium, tantalum, tungsten and cobalt.

22. The target of claim 12 comprising ceramic materials.

23. The target of claim 12 comprising an oxide-containing material.

24. The target of claim 12 comprising one or more of $BaTiO_3$, $Pb(Zr, Ti)O_3$, and $BiSrTaO_3$.

25. A method of forming a sputtering target, comprising:

determining a wear profile for a sputtering target surface, the wear profile corresponding to a shape of the target surface after the target is subjected to the wear of having material sputtered therefrom;

calculating an amount of wear at a plurality of positions of the target surface;

multiplying the amount of wear at the positions by a sputtering uniformity parameter to obtain sputtering uniformity values for the positions, the sputtering uniformity parameter being from 1/16 to 1/6;

adding an additive value to the sputtering uniformity values to generate a desired profile for a sputtering target sputtering surface;

forming a sputtering target with a sputtering surface having the desired profile; said target having an edge region and a central region surrounding the edge region; said target also having a back surface opposing the sputtering surface, said back surface having a substantially planar portion at the edge region and being formed to include an angled region extending between the substantially planar portion of the edge region and the central region, the angle of the angled region being from greater than 1° to about 60° relative to the substantially planar portion of the edge region.

26. A sputtering target formed according to the method of claim 25.

27. A method of forming a sputtering target, comprising:

determining a wear profile for a sputtering target surface, the wear profile corresponding to a shape of the target surface after the target is subjected to the wear of having material sputtered therefrom;

calculating an amount of wear at a plurality of positions of the target surface;

multiplying the amount of wear at the positions by a sputtering uniformity parameter to obtain sputtering uniformity values for the positions, the sputtering uniformity parameter being from 1/16 to 1/6;

adding an additive value to the sputtering uniformity values to generate a desired profile for a sputtering target sputtering surface; and

forming a sputtering target with a sputtering surface having the desired profile.

28. A sputtering target formed according to the method of claim 25.

29. The method of claim 25 wherein the formed sputtering target comprises one or more of aluminum, copper and titanium.

30. The method of claim 25 wherein the formed sputtering target comprises a ceramic material.

31. A method of forming a sputtering target, comprising:

determining a wear profile for a sputtering target surface, the wear profile corresponding to a shape of the target surface after the target is subjected to the wear of having material sputtered therefrom;

calculating an amount of wear at a portion of the target surface relative to other portions of the target surface;

multiplying the amount of wear at the portion by a target lifetime parameter to obtain a first value;

multiplying the amount of wear at the first portion by a sputtering uniformity parameter to obtain a second value, the sputtering uniformity parameter being less than the target lifetime parameter;

multiplying the amount of wear at the other portions by the sputtering uniformity parameter to obtain sputtering uniformity values for the other portions;

using the first value to calculate an additive value;

adding the additive value to at least one of the sputtering uniformity values of the other portions to generate a desired profile for a sputtering target sputtering surface; and

forming a sputtering target with a sputtering surface having the desired profile.

32. The method of claim 30 wherein the additive value is a difference value defined as the difference between the second value and the first value.

33. A sputtering target formed according to the method of claim 30.

34. The method of claim 30 wherein the formed sputtering target comprises one or more of aluminum, copper and titanium.

35. The method of claim 30 wherein the formed sputtering target comprises a ceramic material.

36. The method of claim 30 wherein the target lifetime parameter is greater than 0 and less than or equal to 1.

37. The method of claim 30 wherein the target lifetime parameter is greater than or equal to 0.2 and less than or equal to 0.9.

38. The method of claim 30 wherein the sputtering uniformity parameter is greater than 0 and less than or equal to 1.

39. The method of claim 30 wherein the sputtering uniformity parameter is greater than or equal to 1/16 and less than or equal to 1/6.

40. A method of forming a sputtering target, comprising:

determining a wear profile for a sputtering target surface, the wear profile corresponding to a shape of the target surface after the target is subjected to the wear of having material sputtered therefrom;

allocating the wear profile amongst a plurality of datapoints across the target surface;

for at least some of the datapoints, calculating a difference in height of the target surface after the wear relative to a height of the target surface prior to the wear to generate a plurality of wear definition datapoints;

calculating target lifetime datapoints from at least some of the wear definition datapoints, the calculating the target lifetime datapoints comprising multiplying a magnitude of the at least some of the wear definition datapoints by a target lifetime parameter;

calculating sputtering uniformity datapoints from the at least some of the wear definition datapoints, the calculating the sputtering uniformity datapoints comprising multiplying a magnitude of the at least some of the wear definition datapoints by a sputtering uniformity parameter, the sputtering uniformity parameter being a number less than the target lifetime parameter;

subtracting the target uniformity datapoints from the target lifetime datapoints to obtain difference datapoints;

adding the magnitude of one of difference datapoints to the target uniformity datapoints to generate a desired profile for a sputtering target sputtering surface; and

forming a sputtering target with a sputtering surface having the desired profile.

41. The method of claim 40 further comprising determining which of the difference datapoints has the greatest magnitude, and wherein the magnitude of the difference datapoint with the greatest magnitude is added to the target uniformity datapoints to generate the desired profile for the sputtering target sputtering surface.

42. A sputtering target formed according to the method of claim 40.

43. The method of claim 40 wherein the formed sputtering target comprises one or more of aluminum, copper and titanium.

44. The method of claim 40 wherein the target lifetime parameter is greater than 0 and less than or equal to 1.

45. The method of claim 40 wherein the target lifetime parameter is greater than or equal to 0.2 and less than or equal to 0.9.

46. The method of claim 40 wherein the sputtering uniformity parameter is greater than 0 and less than or equal to 1.

47. The method of claim 40 wherein the sputtering uniformity parameter is greater than or equal to 1/16 and less than or equal to 1/6.

48. A method of forming a sputtering target, comprising:

determining a wear profile for a sputtering target surface, the wear profile corresponding to a shape of the target surface after the target is subjected to the wear of having material sputtered therefrom;

dividing the wear profile amongst a plurality of datapoints across the target surface to generate i datapoints $\{S_1 \ldots S_i\}$, where i is a positive integer;

generating i datapoints corresponding to the height of the target surface prior to the wear, the datapoints being $\{R_1 \ldots R_i\}$;

calculating difference datapoints $\{A_1 \ldots A_i\}$, with each datapoint A_n being defined as $R_n - S_n$;

calculating target lifetime datapoints $\{B_1 \ldots B_i\}$, with each datapoint B_n being defined as $((A_n * y) + Q)$; where y is a constant greater than 0, and Q is a constant which can be 0;

calculating sputtering uniformity datapoints $\{C_1 \ldots C_i\}$, with each datapoint C_n being defined as $((A_n * z) + P)$; where z is a constant greater than 0 and less than y, and wherein P is a constant which can be 0;

calculating difference datapoints $\{D_1 \ldots D_i\}$, with each difference datapoint D_n being defined as $(B_n - C_n)$, and determining which of the difference datapoints has the greatest magnitude, the difference datapoint with the greatest magnitude being defined as D_{max};

calculating a desired surface profile dataset $\{E_1 \ldots E_i\}$, with each datapoint E_n being defined as $(C_n + D_{max})$; and

forming a sputtering target with a sputtering surface having the desired surface profile.

49. The method of claim 48 where P is equal to Q.

50. A sputtering target formed according to the method of claim 48.

51. The method of claim 48 wherein the formed sputtering target comprises one or more of aluminum, copper and titanium.

52. The method of claim 48 wherein y is less than or equal to 1.

53. The method of claim 48 wherein y is greater than or equal to 0.2 and less than or equal to 0.9.

54. The method of claim 48 wherein z is less than or equal to 1.

55. The method of claim 48 wherein z is greater than or equal to 1/16 and less than or equal to 1/6.

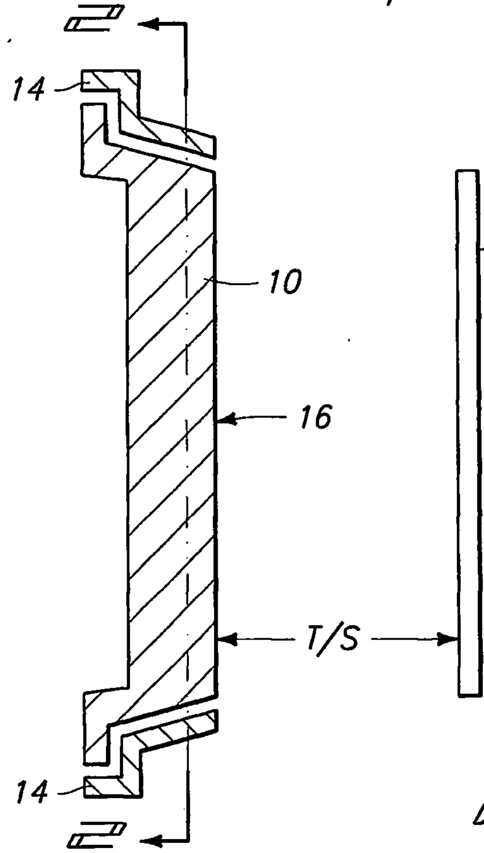

Fig 1
PRIOR ART

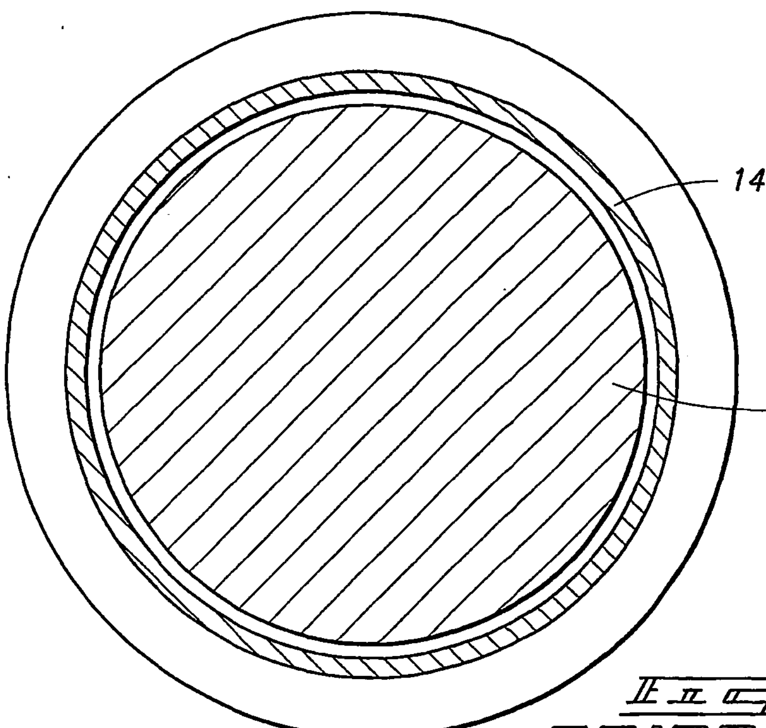

Fig 2
PRIOR ART

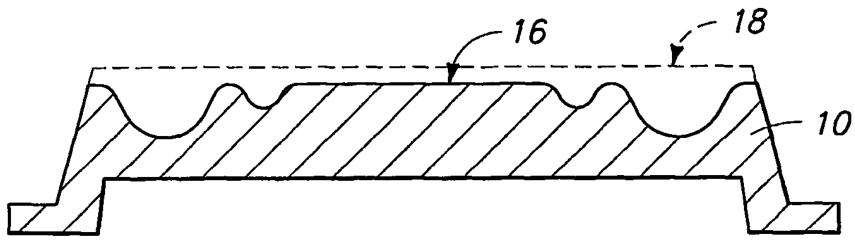

Fig 3
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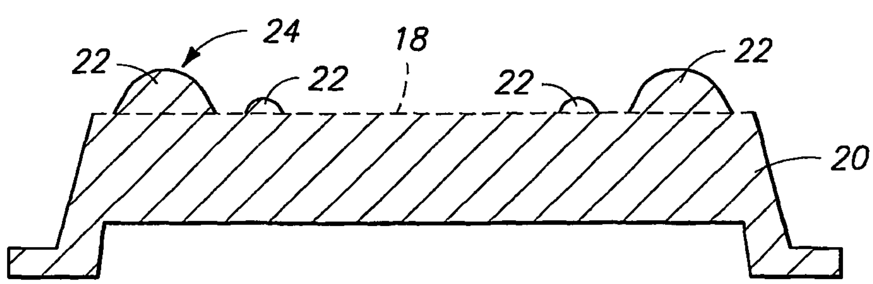

Fig 4
PRIOR ART

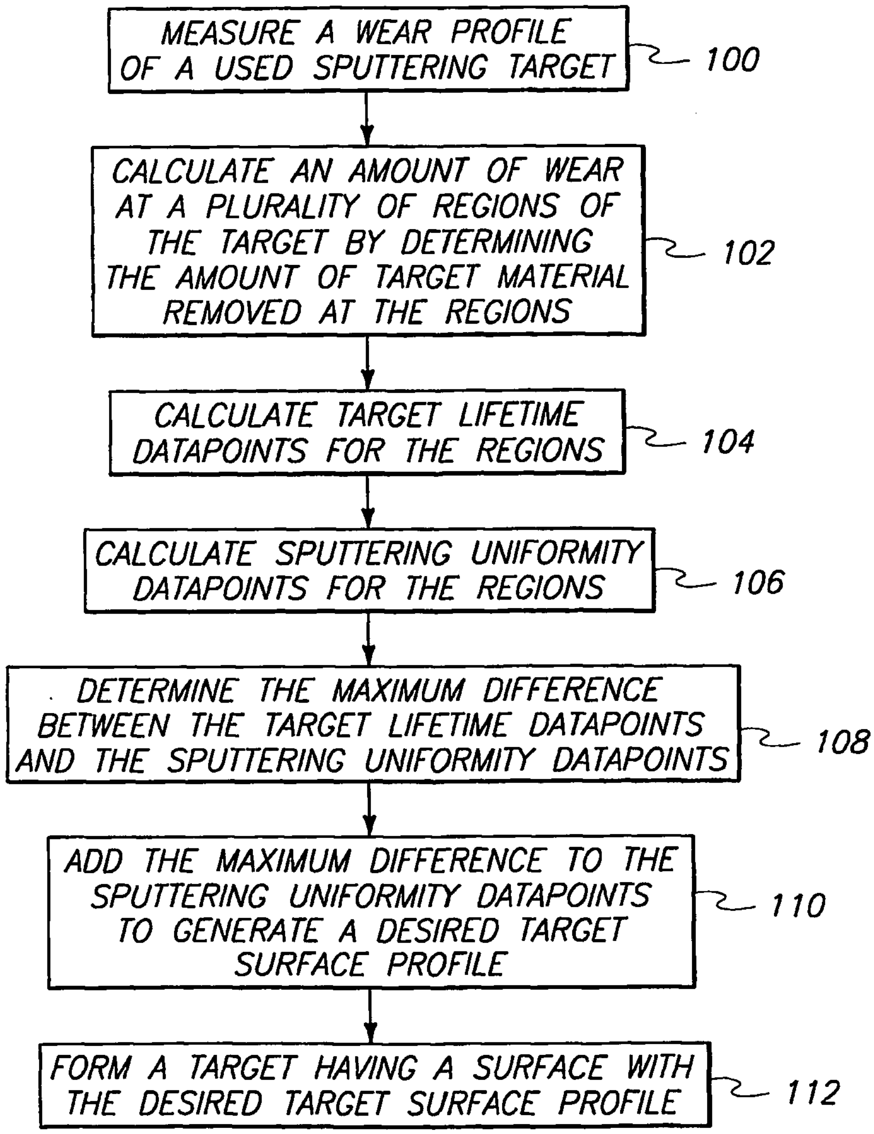
MEASURE A WEAR PROFILE OF A USED SPUTTERING TARGET
100
CALCULATE AN AMOUNT OF WEAR AT A PLURALITY OF REGIONS OF THE TARGET BY DETERMINING THE AMOUNT OF TARGET MATERIAL REMOVED AT THE REGIONS
102
CALCULATE TARGET LIFETIME DATAPOINTS FOR THE REGIONS
104
CALCULATE SPUTTERING UNIFORMITY DATAPOINTS FOR THE REGIONS
106
DETERMINE THE MAXIMUM DIFFERENCE BETWEEN THE TARGET LIFETIME DATAPOINTS AND THE SPUTTERING UNIFORMITY DATAPOINTS
108
ADD THE MAXIMUM DIFFERENCE TO THE SPUTTERING UNIFORMITY DATAPOINTS TO GENERATE A DESIRED TARGET SURFACE PROFILE
110
FORM A TARGET HAVING A SURFACE WITH THE DESIRED TARGET SURFACE PROFILE
112

FIG. 5

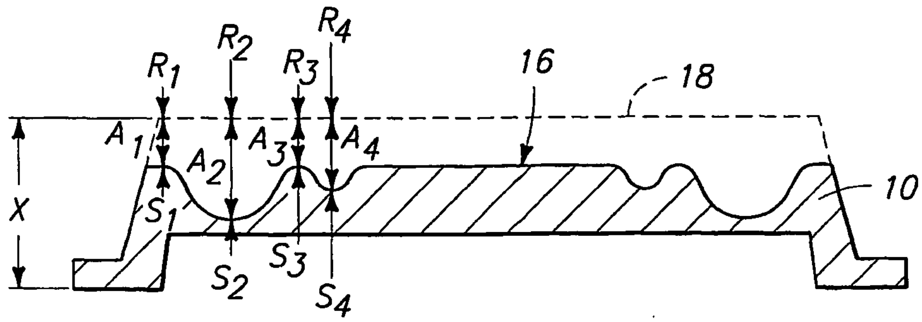

Fig 6

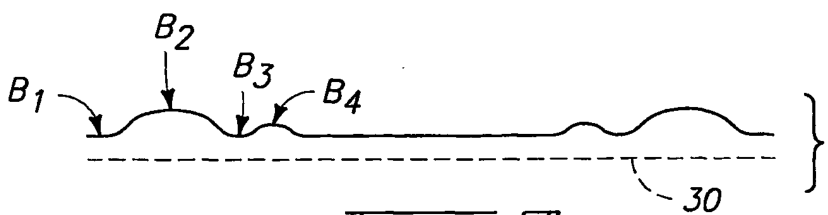

Fig 7

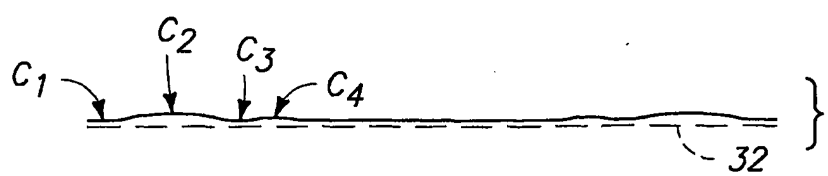

Fig 8

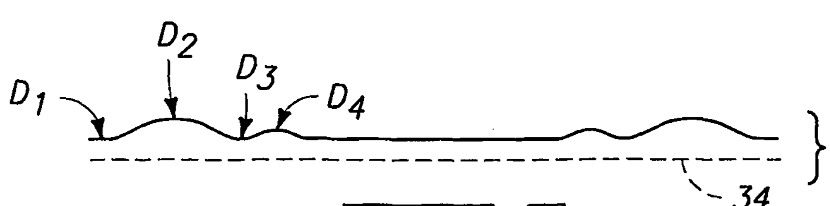

Fig 9

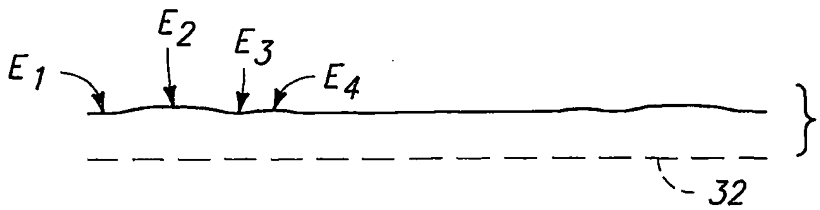

Fig. 10

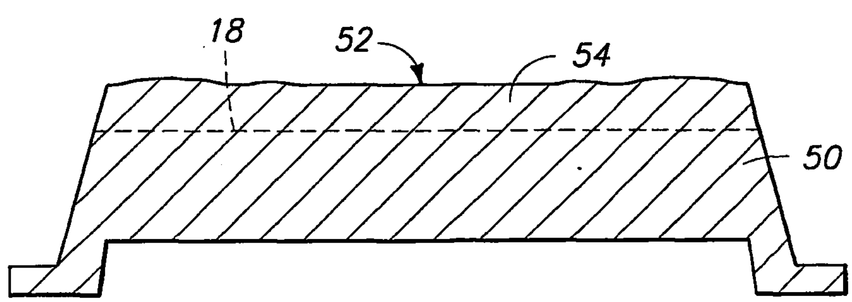

Fig. 11

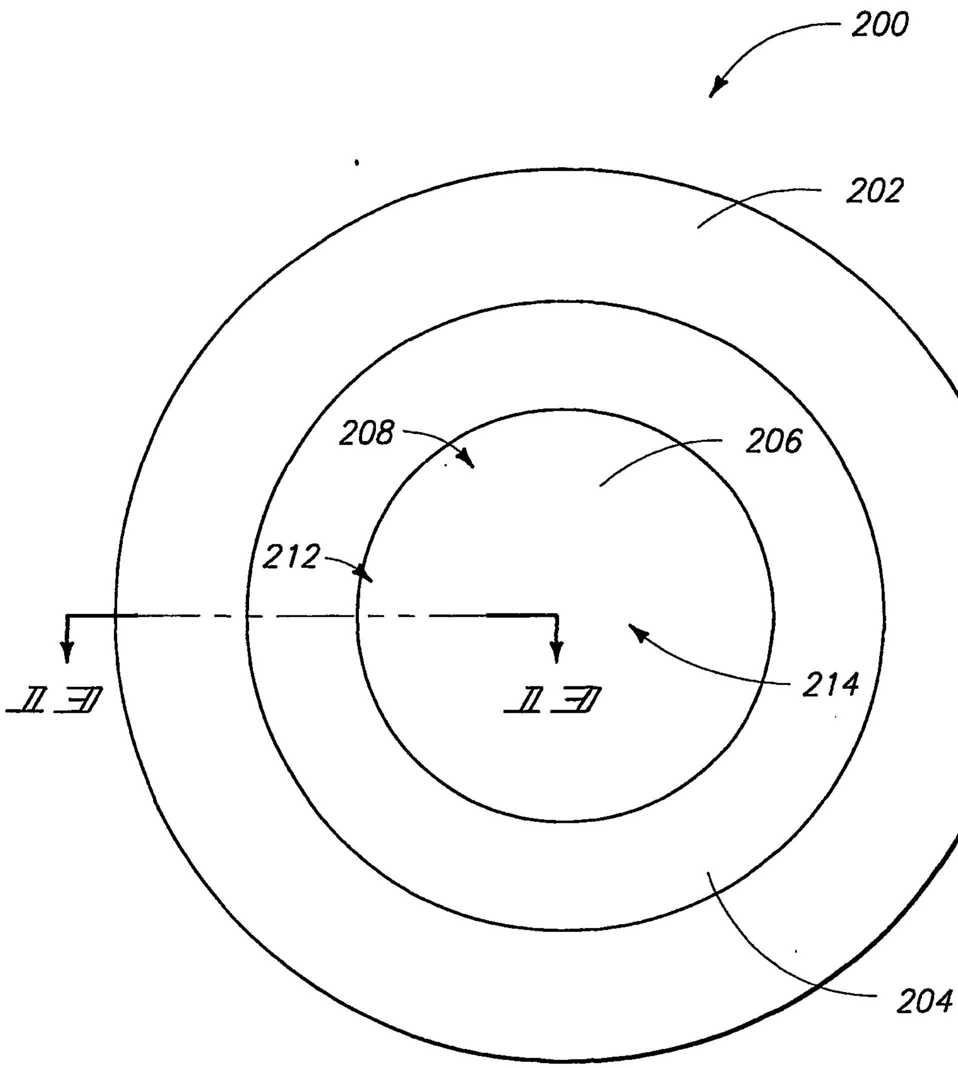

Fig 12

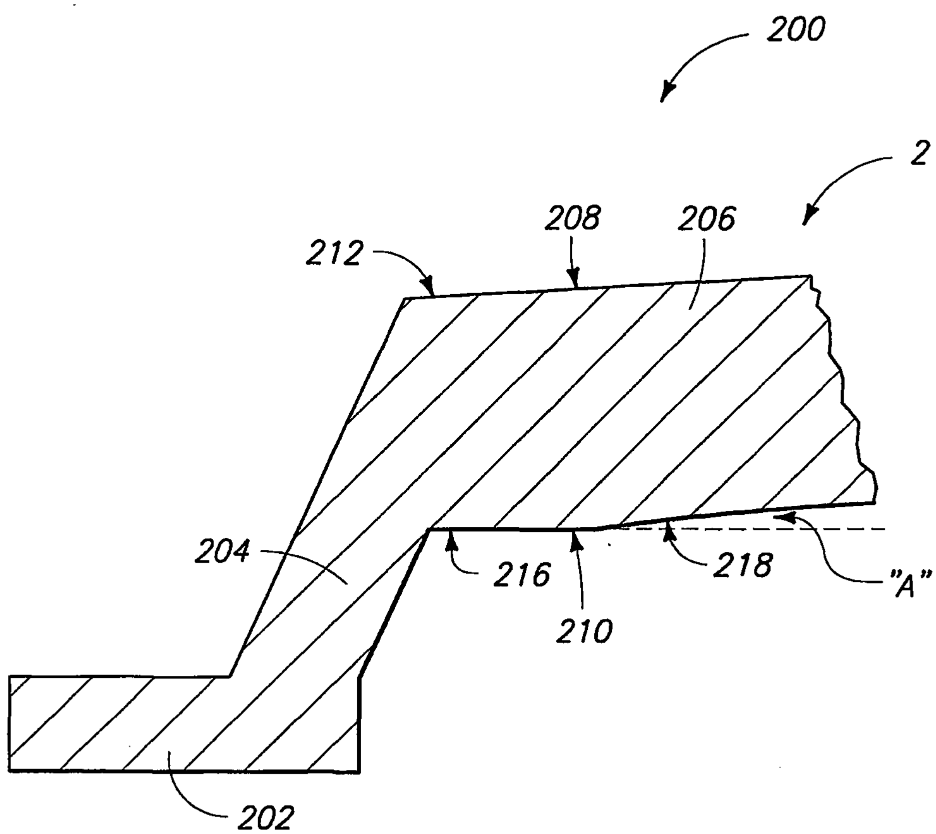

FIG 13